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Description

The present invention is in the field of data communications, and more particularly, relates to the synchronization of terminals in ring communications networks.

Ring communications networks generally include a plurality of terminals coupled in series along a unidirectional signal path. In such communications rings, any of the terminals coupled to the ring may transmit or receive data on the ring according to a ring protocol. In the unusual cases where the terminals are all geographically close together, it is a relatively simple matter to synchronize all the terminals, for example, by providing the clock (or timing) signals for use at the respective terminals from a common oscillator. However, in a more typical ring network environment, there is no readily accessible master oscillator. To achieve interterminal synchronization in such systems timing information is added to the transmitted data. In the prior art for such systems, the ring timing information is inserted by a single terminal. All other terminals adapt their transmit rates to the observed incoming data rates. This approach suffers from the disadvantage of having to identify a crucial terminal.

In an alternate prior art approach, all terminals adapt their transmit rates to the observed identified timing source. In effect, the ring topology permits a distributed averaging of the transmit rate. This approach suffers from its sensitivity to the ring delay and from the timing interdependence among the terminals. In particular, an aberrant terminal can produce a difficult to diagnose error situation.

In an alternate prior art approach, a distributed averaging of the transmit rate is achieved where each terminal has an invariant local oscillator whose frequency is some multiple of the transmit bit rate. A terminal's transmit bit rate is then discretely adjusted in accordance with the observed input data rate. The adjustment occurs in time blocks so that the resultant bit rates through the terminal are varied during those blocks while being substantially fixed at other times. As a result, during the blocks, data packets at various terminals might have the same fixed number of bits pass through, but the bits would have adjustable lengths; adjusted so that there is a predetermined nominal clock rate around the ring. In effect, such systems circulate a synchronization word having a fixed number of bits, where the respective bits are discretely variable in length, due to the adjustment. Between synchronization words, the data is clocked at a fixed frequency. While such systems are effective in many applications, there are disadvantages. For example, the sudden introduction of adjustable length bits requires relatively high bandwidth and also prohibits many forms of transceiver design.

It is an object of the present invention to provide an improved bit synchronization system for a ring communications network.

According to a first aspect of this invention, there is provided a ring communications network comprising a plurality of terminals coupled together to provide a unidirectional communications ring, each of the said terminals including an input port and output port, wherein each terminal has its input port coupled to the output port of the next upstream terminal and has its output port coupled to the input port of the next downstream terminal, and wherein each terminal includes:

A. means for receiving a digital signal at said input port at the data rate associated with the next upstream terminal said received digital signal including a succession of receive data packets interleaved with an associated succession of receive synchronization packets, said data packets having a number of bits less than or equal to a predetermined limit, and said synchronization packets having a number of bits between predetermined maximum and minimum limits.

B. means for detecting each receive synchronization packet and its associated receive data packet,

C. means responsive to said detecting means for generating a succession of transmit synchronization packets and associated transmit data packets at a predetermined fixed transmit data rate associated with said terminal, wherein the data bits of each transmit data packet match bit for bit the data bits of the corresponding receive data packet and wherein the number of bits in the transmit synchronization packet is the same as or is different from the number of bits in the associated receive synchronization packet whereby the data rate for each transmit data packet and its associated transmit synchronization packet corresponds to said transmit data rate associated with said terminal, and

D. means for transmitting said succession of transmit synchronization packets and associated transmit data packets from said output port at said transmit data rate associated with said terminal.

In the preferred form of the invention, the synchronization packet includes a succession of bits having a run with the same binary value (e.g. all binary 1's or all binary 0's) bounded on each end by the opposite binary value. Moreover, data packets may not include a run having bits of the same binary value as the run in the synchronization packets and having a length equal to or greater than the minimum length synchronization packet.

The difference between the number of bits in the transmit synchronization packet and the number of bits in the associated receive synchronization packet may vary between predetermined minimum and maximum limits, and may be zero for two terminals having substantially the same transient bit rate.

In one form of the invention, the transmit data rate for any local terminal is related to the transmit data rate of other terminals on the ring. This relationship may be expressed in terms of the length (L) of data packets where

$$L < W(1 - T^2)/2T$$

where T is the tolerance of the bit rate associated with the terminal and W is representative of the maximum phase jitter of the signal.

In the preferred form of the invention, the detector and transmit generator include a transmit clock generator for generating a transmit clock signal having a repetition rate corresponding to the local terminal transmit data rate. An elastic clock generator generates n elastic clock signals, where n is an integer. Each elastic clock signal has a repetition rate corresponding to the transmit data rate for the local terminal, and each is shifted in time with respect to the transmit clock signal by a different multiple of $1/n \times$ the period of the transmit clock signal.

The preferred form also has a digital sample and hold network adapted to sample and hold the received data signal from the upstream terminal at times determined by an applied one of the elastic clock signals. An output shift register clocks the held samples at the transmit clock rate to generate the transmit data packets and the transmit synchronization packets. A controller is adapted to detect when the sampled and held values correspond to the synchronization packet, and in response to that detection, select one of the elastic clock signals for application to the sample and hold network. Upon such detection, an elastic clock signal is selected which is shifted in time (by a period substantially equal to one-half the period of the transmit clock signal) from the first transition which follows the detected synchronization packet.

Thus, in the preferred form of the invention each local terminal transmits data to the next downstream terminal referenced to that local terminal's own invariant oscillator. The data packets of the received digital signal are interleaved with synchronization packets having elastic length that may be increased or decreased to provide appropriate synchronization around the ring. In effect, synchronization is achieved by a shallow discretely adjusted delay (first in—first out) buffer and sample point readjustment network. The first-in and first-out buffer is read at the fixed transmit data rate, and loaded at that same rate until the period of elasticity is detected. At that point, the sample point is reselected so as to fall substantially in the middle of the transmit bit window effectively changing the first-in first-out buffer depth.

The invention also includes, in a second aspect thereof, a ring communications network comprising a plurality of terminals coupled together to provide a communications ring, each of said terminals being arranged to receive a first digital signal from an upstream terminal in the ring at a data rate associated with the upstream terminal and to transmit a second digital signal to a downstream terminal in the ring at a predetermined transmit data rate associated with the transmitting terminal, wherein the received and transmitted digital signals each include a succes-

sion of data packets interleaved with an associated succession of synchronization packets, and wherein the lengths of the synchronization packets are variable from terminal to terminal to provide synchronization around the ring whilst allowing for different individual terminal transmit data rates.

The invention will now be described by way of example with reference to the drawings, in which:

Figure 1 is a block diagram of an exemplary ring communications network embodying the present invention; and

Figure 2 is a block diagram of a synchronization arrangement in the network of Figure 1.

Referring to Figure 1 of the drawings an exemplary communications network 10 in accordance with the present invention includes four terminals T1, T2, T3, and T4 coupled in series along a unidirectional signal path to form a communications ring. Each of the terminals includes an input port and an output port. The input port of each terminal is coupled to the output port of the upstream terminal and the output port of each terminal is coupled to the input port of the next downstream terminal.

In the system the digital signals passed from terminal to terminal on network 10 include a succession of data packets interleaved with an associated succession of synchronization packets. The transmit data rate for any local terminal is related to the transmit data rate of the other system terminals. This relationship may be expressed in terms of the maximum bit length for a data packet (L) which is

$$L < \frac{W(1 - T^2)}{2T}$$

where T is the frequency tolerance of the local terminal bit rate

$$((f_{\max} - f_{\text{nom}})/f_{\text{nom}})$$

and W is related to the maximum phase jitter per bit ($P_{\max}$) for the system, where

$$W = (T_0 - P_{\max})/T_0,$$

where T_0 is the transmit bit period. Thus less than or equal to a predetermined limit. In addition, the synchronization packets have a number of bits between predetermined minimum and maximum limits, for example, 6 and 14 in the present embodiment. Thus the synchronization packet in effect is a ten-bit word, plus or minus four bits. These limits may differ in other embodiments. Generally, the lower limit for a given nominal synchronization packet length is dependent on the probabilities in the system that successive terminals would have associated bit rates requiring the shaving off of bits of that packet down to the lower limit. The upper limit for a given nominal synchronization packet length is dependent on the system throughput requirements for

data in the data packets and physical media considerations.

In the present embodiment, 1024 bit data packets are used with synchronization packets nominally having ten bits plus or minus four bits. Furthermore, in the present embodiment, the synchronization packets includes a succession of bits all having the same binary "1". Data packets are restricted to have no run of more than five consecutive 1's.

By way of example, the data may be passed from terminal to terminal by a modulated carrier. At each terminal, the received signal may be converted to a demodulated NRZI digital signal. The NRZI signal may be converted to regenerated NRZ data using a phase locked loop. In that operation, the phase locked loop removes amplitude and phase noise from the recovered data.

The reconstructed, PLL referenced, NRZ data has a bit rate determined by the upstream terminal's bit rate. Correspondingly, this rate may vary relative to this local terminal bit rate in accordance with the crystal tolerances, e.g. .0005 percent, and aging parameters, e.g. .0005 percent per year. This difference necessitates a periodic phase adjustment of the PLL-NRZ data to the local terminal bit rate to prevent the local terminal sampling point from drifting too far from the observed center of the bit window. A 1—2 bit variable delay is provided to permit this. When the limits of the delay element are reached, a bit is selectively dropped or added to the passing data stream. In effect, this modulates the transmission rate of the local terminal.

Since the PLL has largely eliminated "edge jitter" in the PLL-NRZ data, the granularity of the delay adjustment is relatively coarse. The minimum adjustment step is the period of the local bit (HS) sample clock. The delay adjustment is done at discrete moments in time. The opportunities for the adjustment are provided by the periodic presence of the synchronization in packets which are interleaved with the passing data packet.

The synchronization packets are identified by a bit pattern whose uniqueness is ensured by the bit stuff protocol. In the present embodiment, in all "1" pattern is bounded by "0—1" and "1—0" transitions. In the present embodiment, there must be at least 6, and there may be no more than 14 consecutive 1's between the 0—1 and 1—0 transition edges. The elasticity in the synchronization packet length accommodates the bit insertion or deletion that takes place when the limits of the variable delay element are reached.

01111110 —Minimum length
synchronization
packet (=6 "one" bits)
0111111111111110 —Maximum length
synchronization

The variable delay is discretely adjusted. It varies from 1 to 2 bit times in steps that are equal in length to the period of a relatively fast local oscillator, the bit sample (HS) clock.

In the preferred embodiment, this delay is introduced by the two cascaded flipflops of blocks 34 and 18. The second flipflop is loaded from the first at an unvarying rate that is equal to the local terminal bit rate (Tx) clock. The first flipflop samples the PLL—NRZ data approximately in the middle of the bit window. The length of the delay is one Tx clock period plus the time between the first flipflop's sampling and the second flipflop's sample loading.

The first flipflop's sample point is reselected whenever a synchronization character passes. A synchronization packet is determined to be passing whenever 6 or more 1's are loaded in succession into this first flipflop. When this occurs, the first flipflop's sampling is inhibited until a binary 0 (synchronized to the HS clock signal) is detected in the PLL-NRZ data. The appearance of this zero starts a counter which determines the optimal sample point. The reselection of the sample point effectively changes the observed delay.

The reselection may alternatively not affect the passing synchronization packet, truncate it by 1 bit, or extend it by 1 bit. The synchronization packet size will only be altered when a delay limit is reached. If the delay is currently at maximum and needs to grow, it will drop back to the minimum and truncate the packet by one bit (unless the minimum packet length limit is reached). If the delay is at minimum and needs to shrink, it will grow to maximum and extend the packet by one bit (unless the maximum packet length limit is reached). If neighboring terminals encounter the worst case frequency mismatch, 1 in 10 synchronization packets will be changed in length.

The re-clocked transmit data (including both the synchronization and data packets) are then re-encoded into the NRZI format before being modulated onto the carrier and transmitted to the next downstream terminal. The encoding is done relative to the terminal's invariant bit rate clock.

Figure 2 shows a synchronizing network 12 in terminal T1 which is similar to corresponding networks in terminals T2—T4. The remaining portions of terminal T1 (for example, devices adapted for interface with other equipment, access control, and the like) are not shown in Figure 2. The synchronizing network 12 includes input stage 14 coupled to the input port by way of line 14a, an output stage 18 coupled to the output port by way of line 18a, and an intermediate stage 16 coupling stages 14 and 18.

In the present embodiment, the input stage 14 includes a phase locked loop (PLL) clock recovery network 20 and a shift register 22. The PLL network 20 extracts a receive (Rx) clock signal from the signal received from terminal T4. The Rx clock signal is applied to shift register 22 to regenerate the data signal applied by way of line 14a in synchronization with the extracted Rx clock signal. This regenerated data signal on line 22a is applied to the intermediate stage 16.

Stage 18 includes an output shift register 24 and a transmit clock generator 26. The transmit clock generator 26 produces a transmit (Tx) clock signal

at a repetition rate corresponding to the predetermined, fixed transmit data rate associated with the terminal T₁. The shift register 24 is clocked by that T_x clock signal and a digital signal applied by way of line 24a to provide a digital signal to the downstream terminal T₂ at the transmit data rate associated with terminal T₁.

In the present embodiment, the intermediate stage 16 includes a high speed clock generator 30, elastic clock generator 32, a digital sample and hold network 34 and a controller 38. The controller 38 includes a clock selector 40, synchronization word detector 42, end-of-sync (EOS) detector 44, and shift register delay 45.

In the present embodiment, the high speed clock generator 30 generates a high speed (HS) clock signal which is eight times the repetition rate of the transmit clock signal, and synchronous with that transmit clock signal. The elastic clock generator 32 is coupled to the generator 30 and produces eight elastic clock signals, $\emptyset_1, \emptyset_2, \dots, \emptyset_8$, each having a repetition rate corresponding to the transmit data rate. Each of the signals produced by the elastic clock generator 32 is shifted in time with respect to transmit (T_x) clock signal by a different multiple of 1/8 times the period of the transmit clock signal. In other embodiments, different numbers (than eight) of signals may be produced by the clock generator which are also phased appropriately.

The clock selector 40 is adapted to select one of the elastic clock signals and apply that signal by way of line 40a to the clock input of the sample and hold network 34. Network 34 in this embodiment includes a single shift register stage having its data input coupled to line 22a and its data output coupled to line 24a. The application of a clock pulse to the clock input of shift register of network 34 produces a transfer of the binary value at the data input (i.e. line 22a) to the data output (i.e. line 24a) of that shift register.

The synchronization word detector 42 has an input coupled to the line 22a, and a clock input driven by the elastic clock signal on line 40a.

The EOS detector 44 is coupled to line 22a and is adapted to detect transitions in the data on that line. The output of detector 44 is clocked through a shift register delay 45 at the HS clock rate so that the EOP (end-of-packet) signal occurs four periods of the HS clock signal after the detected transition.

In operation, the clock selector 40 applies one of the elastic clock signals to the sample and hold network 34. The synchronization word detector 42 monitors the digital signal on line 22a. Upon detection of the synchronization packet, i.e. detecting at least six consecutive binary ones, the detector 42 generates a signal to disable the clock selector 40. As a result, an "extended binary one" is in effect produced on line 24a at this time.

Following the sync word detection by detector 42, the end-of-sync (EOS) detector 44 monitors the line 22a to detect the first transition, indicating the end of the synchronization packet. At the latter detection, EOS detector 44 and delay 45 generate

an end-of-packet (EOP) signal following n/2 repetition periods of the HS clock signal. This EOP signal is applied to the enable input of clock selector 40, which in turn selects the elastic clock signal ($\emptyset_1, \emptyset_2, \dots, \emptyset_8$) which has a transition closest to the EOP signal, and applies that selected elastic clock signal to line 40a until the selector 40 is next disabled.

Until that disablement, the data packet on line 22a is clocked through element 34 in response to the selected elastic clock signal. In this manner, the composite data packets and synchronization packets from element 34 may be clocked through register 24 and to terminal T₂ at the T_x clock rate.

The invention may be embodied in other specific forms without departing from the essential characteristics thereof. The present embodiments are therefore to be considered as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning of the claims are therefore intended to be embraced therein.

Claims

1. A ring communications network comprising a plurality of terminals coupled together to provide a unidirectional communications ring, each of said terminals including an input port and an output port,

wherein each terminal has its input port coupled to the output port of the next upstream terminal and has its output port coupled to the input port of the next downstream terminal, and wherein each terminal includes:

A. means for receiving a digital signal at said input port at the data rate associated with the next upstream terminal, said received digital signal including a succession of receive data packets interleaved with an associated succession of receive synchronization packets, said data packets having a number of bits less than or equal to a predetermined limit, and said synchronization packets having a number of bits between predetermined maximum and minimum limits,

B. means for detecting each receive synchronization packet and its associated receive data packet,

C. means responsive to said detecting means for generating a succession of transmit synchronization packets and associated transmit data packets at a predetermined fixed transmit data rate associated with said terminal, wherein the data bits of each transmit data packet match bit for bit the data bits of the corresponding receive data packet and wherein the number of bits in the transmit synchronization packet is the same as or is different from the number of bits in the associated receive synchronization packet whereby the data rate for each transmit data packet and its associated transmit synchronization packet corresponds to said transmit data rate associated with said terminal, and

D. means for transmitting said succession of transmit synchronization packets and associated

transmit data packets from said output port at said transmit data rate associated with said terminal.

2. A ring communications network according to Claim 1 wherein said detecting means and said generating means includes:

transmit clock generating means for generating a transmit (T_x) clock signal, said T_x clock signal having a repetition rate corresponding to said transmit data rate,

high speed clock generating means for generating a high speed (HS) clock signal, said HS clock signal having a repetition rate n times said transmit data rate, where n is an integer, and being synchronized with said T_x clock signal,

synchronization detector means for detecting said synchronization packet at said input port and for generating a synchronization (S) signal representative of said detection,

a first shift register having a data input line coupled to said input port, a data output line coupled to said signal line, and an elastic clock input line,

a second shift register having a data input line coupled to said signal line, a data output line coupled to said output port, and

a transmit clock input line coupled to said transmit clock generating means, said second shift register being adapted to shift binary levels at its data input line to its data output line in response to said T_x clock signal applied to its transmit clock input line,

a transition detector means coupled to said input port and including means for detecting logic transitions of said digital signal at said input port, and means operative following detection of said synchronization packet for generating an end-of-packet (EOP) signal following $n/2$ repetition periods of said HS clock signal after the next logic transition of said signal at said input port, and

a selectively operable elastic clock generating means coupled to said high speed clock generating means and responsive to said HS clock signal, said S signal, and said EOP signal for generating an elastic clock signal synchronous with said EOP signal and at $1/n$ of the rate of said HS clock signal applied thereto, said elastic clock generating means including means for coupling said elastic clock signal to said elastic clock input line, wherein said elastic clock generating means is disabled following an applied S signal, and is enabled following an applied EOP signal.

3. A ring communications network according to Claim 1 wherein the data packet length (L) is

$$L < W(1 - T^2)2T,$$

where T is the tolerance of the bit rate associated with said terminal and W is representative of the maximum phase jitter for said data signal, wherein said detecting means and said generating means includes:

transmit clock generating means for generating a transmit (T_x) clock signal, said T_x clock signal having a repetition rate corresponding to said transmit data rate,

elastic clock generating means for generating n elastic clock signals, where n is an integer, each elastic clock signal having a repetition rate corresponding to said transmit data rate, and each being shifted in time with respect to said T_x clock signals by a different multiple of $1/n$ times the period of said T_x clock signal,

means for sampling and holding said received data signal at times determined by an applied one of said elastic clock signals,

shift register means for clocking said held samples with said T_x clock signal to generate said transmit data packets and said transmit synchronization packets,

controller including means for detecting when said sampled and held values correspond to said synchronization packet and in response to said detection selecting one of said elastic clock signals and applying said selected elastic clock signal to said sample and hold means, whereby said selected elastic clock signal is the elastic clock signal which is shifted in time by a period substantially equal to one-half the period of said T_x clock signal from the first transition in said received data signal following detected synchronization packet.

4. A ring communications network comprising a plurality of terminals coupled together to provide a communications ring, each of said terminals being arranged to receive a first digital signal from an upstream terminal in the ring at a data rate associated with the upstream terminal and to transmit a second digital signal to a downstream terminal in the ring at a predetermined transmit data rate associated with the transmitting terminal, wherein the received and transmitted digital signals each include a succession of data packets interleaved with an associated succession of synchronization packets, and wherein the lengths of the synchronization packets are variable from terminal to terminal to provide synchronization around the ring whilst allowing for different individual terminal transmit data rates.

Patentansprüche

1. Ringförmiges Kommunikationsnetzwerk mit mehreren Terminals, die so miteinander verbunden sind, daß sie einen Kommunikationsring für eine Übertragung in nur einer Richtung bilden, wobei jedes Terminal einen Eingang und einen Ausgang aufweist und sein Eingang mit dem Ausgang des bezüglich der Kommunikationsrichtung vorgehenden Terminals und sein Ausgang mit dem Eingang des nachfolgenden Terminals verbunden ist und wobei jedes Terminal folgende Komponenten aufweist:

A. eine Einrichtung zum Empfang eines digitalen Signals am Eingang, mit einer Datenrate, die dem vorhergehenden Terminal zugeordnet ist, wobei das empfangene digitale Signal aus einer Folge von Empfangsdatenpaketen besteht, die mit einer zugeordneten Folge von Empfangssynchronisationspaketen verschachtelt sind und die Datenpakete eine Anzahl von Bits aufweisen, die größer

oder gleich einem vorgegeben Grenzwert ist und die Synchronisationspakete über eine Anzahl von Bits verfügen, die zwischen vorgegebenen maximalen und minimalen Grenzwerten liegt,

B. eine Detektoreinrichtung zur Feststellung von Empfangssynchronisationspaketen und deren zugeordneten Empfangsdatenpaketen,

C. eine Generatoreinrichtung, die in Abhängigkeit von der Detektoreinrichtung eine Folge von Sendesynchronisationspaketen und diesen zugeordneten Sendedatenpaketen mit einer vorgegebenen festen Übertragungsdatenrate erzeugt, die dem genannten Terminal zugeordnet ist, wobei die Datenbits in jedem Sendedatenpaket bitweise mit den Datenbits des entsprechenden Empfangsdatenpakets Übereinstimmen und wobei die Anzahl der Bits in dem Sendesynchronisationspaket gleich oder unterschiedlich der Zahl von Bits in dem zugeordneten Empfangssynchronisationspaket ist und die Datenrate für jedes Sendedatenpaket und dessen zugeordnetes Sendesynchronisationspaket der genannten Übertragungsdatenrate des genannten Terminals entspricht und

D. eine Übertragungseinrichtung für die Übertragung der genannten Folge von Sendesynchronisationspaketen und deren zugeordneten Sendedatenpaketen vom genannten Ausgang mit einer Datenrate, die dem genannten Terminal zugeordnet ist.

2. Ringförmiges Kommunikationsnetzwerk nach Anspruch 1, bei dem die genannte Detektoreinrichtung und die genannte Generatoreinrichtung folgende Komponenten aufweisen:

eine Sendetakterzeugereinrichtung zur Erzeugung eines Sendetaktsignals (T_x), das eine Signalwiederholungsrate aufweist, die der genannten Sendedatenrate entspricht,

eine Hochgeschwindigkeitstakterzeugereinrichtung für die Erzeugung eines Hochgeschwindigkeitstaktsignals (ES), das eine Signalwiederholungsrate aufweist, die n mal höher ist als die genannte Sendedatenrate, wobei n ganzzahlig ist und das mit dem genannten T_x -Takt signal synchronisiert ist,

eine Synchronisationsdetektoreinrichtung zur Feststellung des genannten Synchronisationspakets an dem genannten Eingang und zur Erzeugung eines Synchronisationssignals (S), das für eine solche Feststellung repräsentativ ist,

ein erstes Schieberegister, dessen Dateneingangsleitung mit dem genannten Eingang verbunden ist, einer Datenausgangsleitung, die mit der genannten Signalleitung verbunden ist, sowie mit einer Eingangsleitung für einen elastischen Takt,

ein zweites Schieberegister, dessen Dateneingangsleitung mit der genannten Signalleitung und dessen Datenausgangsleitung mit dem genannten Ausgang verbunden ist und mit

einer Sendetakteingangsleitung, die mit der genannten Sendetakterzeugereinrichtung verbunden ist, wobei das zweite Schieberegister geeignet ist, binäre Signalpegel an seiner Dateneingangsleitung zu seiner Datenausgangsleitung in Abhängigkeit von dem T_x -Takt signal, das an

seine Sendetakteingangsleitung angelegt ist, zu verschieben,

eine Signalübergangsdetektoreinrichtung, die mit dem genannten Eingang verbunden ist und Mittel zur Feststellung logischer Signalübergänge des genannten digitalen Signals an dem genannten Eingang, sowie Mittel aufweist, die nach der Feststellung eines genannten Synchronisationspaketes ein Paketendesignal (EOP) nach $n/2$ Wiederholungsperioden des genannten ES-Takt signals, nach dem nächsten logischen Signalübergang des genannten Signals, am genannten Eingang erzeugen und

eine selektiv arbeitende Erzeugereinrichtung für den elastischen Takt, die mit der Hochgeschwindigkeitstakterzeugereinrichtung verbunden ist und beim Auftreten des genannten ES-Takt signals des genannten S-Signals und des genannten EOP-Signals ein elastisches Takt signal erzeugt, das mit dem genannten EOP-Signal synchron ist und $1/n$ -tel der Taktrate des genannten ES-Takt signals, des hieran anliegt, beträgt, wobei die genannte Erzeugereinrichtung für den elastischen Takt Mittel zum Anlegen des elastischen Taktes an die genannte Eingangsleitung für den elastischen Takt aufweist, und

die genannte Erzeugereinrichtung für den elastischen Takt nach dem Anlegen eines S-Signals abgeschaltet und nach einem angelegten EOP-Signal eingeschaltet wird.

3. Ringförmiges Kommunikationsnetzwerk nach Anspruch 1, bei dem die Datenpaketlänge (L)

$$L < W(1 - T^2)/2T \text{ ist,}$$

wobei T die Toleranz der dem genannten Terminal zugeordneten Bitrate ist und W dem maximalen Phasenversatz des genannten Datensignals entspricht, wobei die genannte Detektoreinrichtung und die genannte Generatoreinrichtung folgende Komponenten aufweisen:

eine Sendetakterzeugereinrichtung zur Erzeugung eines Sendetaktsignals (T_x) mit einer Signalwiederholungsrate, die der Sendedatenrate entspricht,

eine Takterzeugereinrichtung zur Erzeugung von n elastischen Takt signalen, wobei n ganzzahlig und die Signalwiederholungsrate des elastischen Takt signals der genannten Sendedatenrate entspricht und jedes zeitverschoben um ein anderes Mehrfaches von $1/n$ mal der Periode des genannten T_x -Takt signals gegenüber dem genannten T_x -Takt signal ist,

eine Abtast- und Halteeinrichtung, die das empfangene Datensignal zu Zeitpunkten, die durch eines der angelegten genannten elastischen Takt signale bestimmt sind, abfühlt und festhält,

ein Schieberegister zum Takten der festgehaltenen Abtastwerte mit dem genannten T_x -Takt signal zur Erzeugung der genannten Sendedatenpakete und der genannten Sendesynchronisationspakete und

eine Steuereinrichtung, einschließlich einer Einrichtung zur Feststellung, wenn die genannten

abgefügten und festgehaltenen Werte dem genannten Synchronisationspaket entsprechen und, in Abhängigkeit von der genannten Feststellung, zur Selektion eines der genannten elastischen Taktsignale und Anlegen des genannten selektierten elastischen Taktsignals an die genannte Abtast- und Halteeinrichtung, wodurch das selektierte elastische Taktsignal dasjenige elastische Taktsignal ist, welches zeitlich um eine Periode verschoben ist, die im wesentlichen gleich einer halben Periode des genannten T_x -Taktsignals, gerechnet vom ersten Signalübergang im genannten empfangenen Datensignal nach dem festgestellten Synchronisationspaket ist,

4. Ringförmiges Kommunikationsnetzwerk mit mehreren, zu einem Kommunikationsring zusammengeschalteten Terminals, von denen jedes ein erstes Datensignal von einem bezüglich des Kommunikationsflusses vorhergehenden Terminal im Ring mit einer Datenrate empfängt, die dem vorhergehenden Terminal entspricht und zur Übertragung eines zweiten Digitalsignals zu einem nachfolgenden Terminal im Ring mit einer vorgegebenen Sendedatenrate, die dem sendenden Terminal zugeordnet ist, wobei die empfangenen und gesendeten digitalen Signale jeweils eine Folge von Datenpaketen enthalten, die mit einer zugeordneten Folge von Synchronisationspaketen verschachtelt sind und wobei die Längen der Synchronisationspakete von Terminal zu Terminal variabel sind, um eine Synchronisation längs des Rings zu ermöglichen, während verschiedene individuelle Terminalübertragungsraten zugelassen sind.

Revendications

1. Réseau de communications en anneau comprenant une multiplicité de terminaux reliés ensemble de façon à fournir un anneau de communications unidirectionnel, chacun desdits terminaux comportant un port d'entrée et un port de sortie,

dans lequel chaque terminal a son port d'entrée relié au port de sortie du terminal situé immédiatement en amont et son port de sortie relié au port d'entrée du terminal situé immédiatement en aval, et dans lequel chaque terminal comporte:

A. Des moyens pour recevoir un signal numérique à son port d'entrée au débit associé au terminal situé immédiatement en amont, ledit signal numérique reçu comportant une succession de paquets de données de réception entrelacés avec une succession associée de paquets de synchronisation de réception, lesdits paquets de données comportant un nombre de bits inférieur ou égal à une limite prédéterminée, et lesdits paquets de synchronisation comportant un nombre de bits compris entre des limites maximale et minimale prédéterminées,

B. Des moyens pour détecter chaque paquet de synchronisation de réception et le paquet de données de réception qui lui est associé,

C. Des moyens sensibles auxdits moyens de

détection pour produire une succession de paquets de synchronisation de transmission et de paquets de données de transmission associées à un débit de transmission prédéterminé fixe associé audit terminal, les bits de données de chaque paquet de données de transmission correspondant bit pour bit aux bits de données du paquet de données de réception correspondant et le nombre de bits dans le paquet de synchronisation de transmission étant identique ou différent du nombre de bits dans le paquet de synchronisation de réception associé, le débit pour chaque paquet de données de transmission et le paquet de synchronisation de transmission qui lui est associé correspondant ainsi audit débit de transmission associé au terminal, et

D. Des moyens pour transmettre ladite succession de paquets de synchronisation de transmission et de paquets de données de transmission à partir du port de sortie audit débit de transmission associé au terminal.

2. Réseau de communications en anneau selon la revendication 1, dans lequel lesdits moyens de détection et lesdits moyens de production comprennent:

des moyens générateurs d'horloge de transmission pour produire un signal d'horloge de transmission (T_x), ledit signal d'horloge T_x ayant une cadence de répétition correspondant audit débit de transmission,

des moyens générateurs d'horloge à grande vitesse pour produire un signal d'horloge à grande vitesse (HS), ledit signal d'horloge HS ayant une cadence de répétition de n fois ledit débit de transmission, n étant un nombre entier, et étant synchronisé avec ledit signal d'horloge T_x ,

des moyens détecteurs de synchronisation pour détecter ledit paquet de synchronisation au port d'entrée et pour produire un signal de synchronisation (S) représentatif de cette détection,

un premier registre à décalage présentant une ligne d'entrée de données relié au port d'entrée, une ligne de sortie de données reliée à ladite ligne de signal, et une ligne d'entrée d'horloge élastique,

un second registre à décalage présentant une ligne d'entrée de données reliée à ladite ligne de signal, une ligne de sortie de données reliée au port de sortie, et

une ligne d'entrée d'horloge de transmission reliée aux moyens générateurs d'horloge de transmission, le second registre à décalage étant propre à décaler des niveaux binaires de sa ligne d'entrée de données à sa ligne de sortie de données en réponse au signal d'horloge T_x appliqué à sa ligne d'entrée d'horloge de transmission,

des moyens détecteurs de transition reliés au port d'entrée et comportant des moyens pour détecter des transitions logiques dudit signal numérique au port d'entrée, et des moyens agissant à la suite de la détection dudit paquet de synchronisation pour produire un signal de fin de paquet (EOLP) après $n/2$ périodes de répétition dudit signal d'horloge ES consécutives à la transi-

tion logique suivante dudit signal au port d'entrée et

des moyens générateurs d'horloge élastique pouvant être mis en oeuvre sélectivement, reliés auxdits moyen générateurs d'horloge à grande vitesse et sensibles audit signal d'horloge HS, audit signal S et audit signal EOP pour produire un signal d'horloge élastique synchrone du signal EOP et à $1/n$ du débit du signal d'horloge ES qui lui est appliqué, les moyens générateurs d'horloge élastique comportant des moyens pour relier le signal d'horloge élastique à la ligne d'entrée d'horloge élastique, les moyens générateurs d'horloge élastique étant mis hors service à la suite de l'application d'un signal S et en service à la suite de l'application d'un signal EOP.

3. Réseau de communications en anneau selon la revendication 1, dans lequel la longueur (L) du paquet de données est

$$L < W(1 - T^2)/2T,$$

T étant la tolérance du débit associé au terminal et W représentant le bruit de phase maximal pour ledit signal de données, dans lequel lesdits moyens de détection et lesdits moyens générateurs comprennent:

des moyens générateurs d'horloge de transmission pour produire un signal d'horloge de transmission (T_x), ledit signal d'horloge T_x ayant une cadence de répétition correspondant audit débit de transmission,

des moyens générateurs d'horloge élastique pour produire n signaux d'horloge élastique, n étant un nombre entier, chaque signal d'horloge élastique ayant une cadence de répétition correspondant audit débit de transmission et chacun étant décalé dans le temps par rapport au signal d'horloge T_x d'un multiple différent de $1/n$ fois la période du signal d'horloge T_x ,

des moyens pour échantillonner et bloquer ledit

signal de données reçu à des instants déterminés par l'un des signaux d'horloge élastique qui est appliqué.

des moyens de registre à décalage pour rythmer les échantillons bloqués à l'aide du signal d'horloge T_x pour produire les paquets de données de transmission et les paquets de synchronisation de transmission,

un organe de commande comprenant des moyens pour détecter le moment où les valeurs échantillonnées et bloquées correspondant audit paquet de synchronisation et, en réponse à cette détection, choisir l'un desdits signaux d'horloge élastique et appliquer ce signal d'horloge élastique choisi aux moyens d'échantillonnage et de blocage, ce signal d'horloge élastique choisi étant le signal d'horloge élastique qui est décalé dans le temps d'une durée sensiblement égale à la demi-période du signal d'horloge T_x à partir de la première transition du signal de données reçu suivant le paquet de synchronisation détecté.

4. Réseau de communications en anneau comprenant une multiplicité de terminaux reliés ensemble pour fournir une boucle de communication, chacun desdits terminaux étant agencé pour recevoir un premier signal numérique d'un terminal situé en amont dans la boucle à un débit associé au terminal amont et pour transmettre un second signal numérique à un terminal situé en aval dans la boucle à un débit de transmission prédéterminé associé au terminal qui effectue la transmission, les signaux numériques reçu et transmis contenant chacun une succession de paquets de données entrelacés avec une succession associée de paquets de synchronisation, et la longueur des paquets de synchronisation étant variable d'un terminal à l'autre pour réaliser une synchronisation le long de la boucle tout en permettant des débits de transmission de terminaux individuels différents.

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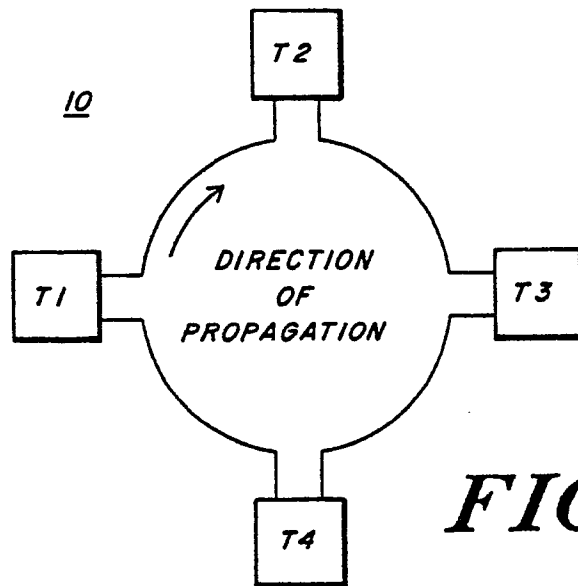


FIG. 1

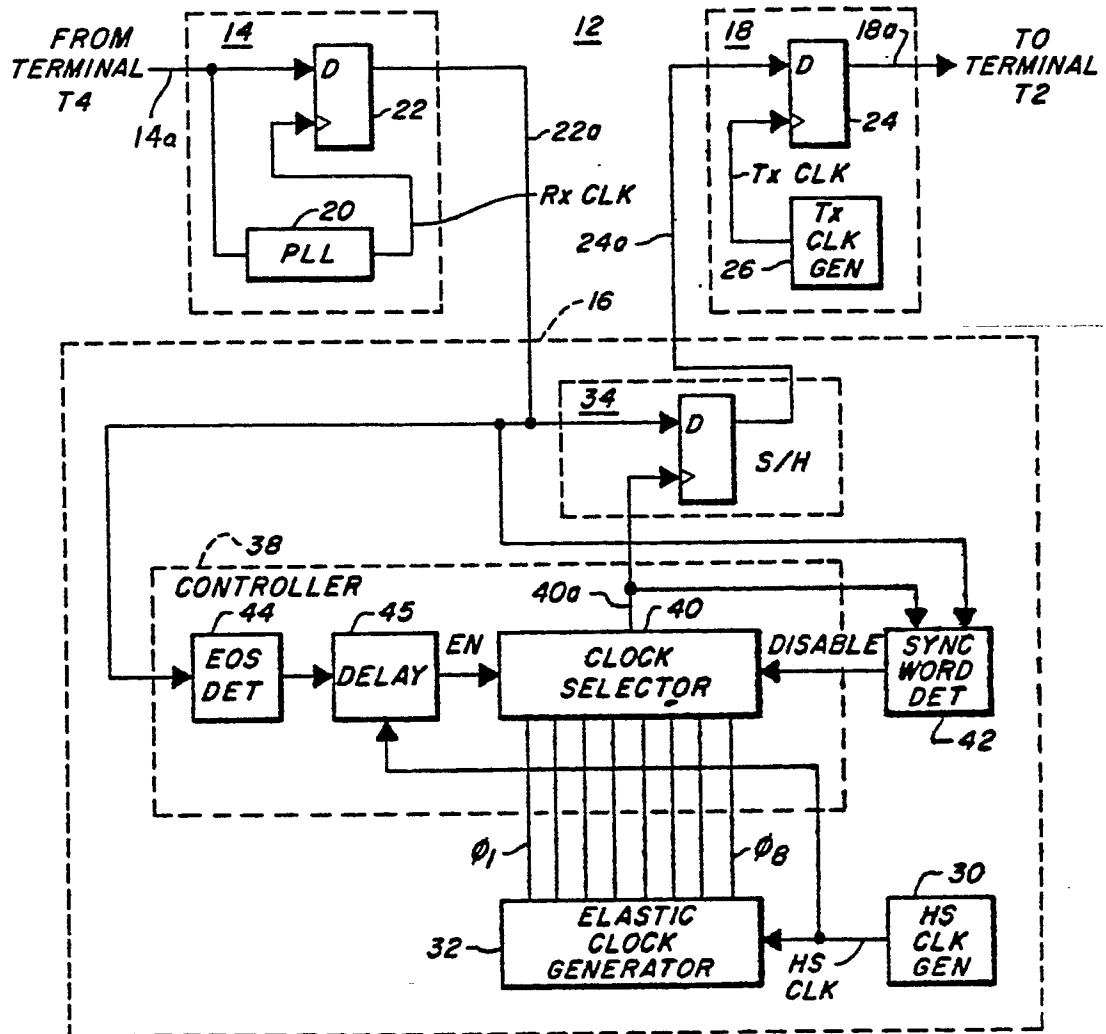


FIG. 2